US Army Corps of Engineers

AD-A237 421

MISCELLANEOUS PAPER EL-91-16

EFFECTS OF MICROTOPOGRAPHIC FEATURES ON TILT OF THE WIDE AREA MINE GROUND PLATFORM

by

Bruce Sabol, Tommy Berry

Environmental Laboratory

DEPARTMENT OF THE ARMY
Waterways Experiment Station, Corps of Engineers
3909 Halls Ferry Road Vicksburg, Mississippi 39180-6199

US ARMY ENGINEER WATERWAYS EXPERIMENT STATION

May 1991

Final Report

Approved For Public Release, Distribution Unlimited

Prepared for DEPARTMENT OF THE ARMY
US Army Corps of Engineers
Washington, DC 20314-1000

ENVIRONMENTAL LABORATORY

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave blank)*

2. REPORT DATE
May 1991

3. REPORT TYPE AND DATES COVERED
Final report

4. TITLE AND SUBTITLE
Effects of Microtopographic Features on Tilt of the Wide Area Mine Ground Platform

5. FUNDING NUMBERS

6. AUTHOR(S)
Bruce Sabol
Tommy Berry

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
USAEWES, Environmental Laboratory,
3909 Halls Ferry Road, Vicksburg, MS 39180-6199

8. PERFORMING ORGANIZATION REPORT NUMBER
Miscellaneous Paper EL-91-16

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
US Army Corps of Engineers, Washington, DC 20314-1000

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES
Available from National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161

12a. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

Under the Proof of Principle Program for development of the Wide Area Mine (WAM), the US Army Engineer Waterways Experiment Station (WES) were responsible for characterizing terrain features expected to affect the WAM performance. The off-vertical angle of the WAM ground platform (tilt) erected on the terrain surface will affect several critical functions of candidate WAM systems. Digital terrain elevation data of adequate spatial resolution (2-ft horizontal spacing) was not available to accurately estimate the distribution of tilt angles for the WAM ground platforms. Actual tilt measurements were therefore made on pre-erected (legs locked in place) WAM surrogates (mass models) on four terrain surface types representing managed and agricultural lands.

Mean tilt angles ranged from 2 deg for meadowland to almost 11 deg for a freshly plowed and rowed field. The Textron Defense System WAM exhibited a slightly larger mean and standard deviation of tilt angle than the Honeywell, Inc., WAM for each terrain surface type; however, this difference was statistically significant in only one of the four cases. Because this study did not consider the ground platform erection process, these data should not be interpreted as tilt angles resulting from realistic deployment of WAMs.

14. SUBJECT TERMS

Agricultural land	Terrain	WAM
Mine use	Testing	Wide Area Mine
Surface roughness	Tilt	

15. NUMBER OF PAGES
26

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
UNCLASSIFIED	UNCLASSIFIED		

Contents

Preface

The study reported herein was conducted by the US Army Engineer Waterways Experiment Station (WES) during fiscal years 1989-90. It was funded by the US Army Armament Research Development and Engineering Center (ARDEC), Picatinny Arsenal, New Jersey, in support of the Wide Area Mine (WAM) Proof-of-Principle Program. Mr. George Lutz was the ARDEC Technical Monitor.

This study was conducted under the general supervision of Dr. John Harrison, Chief of the Environmental Laboratory (EL), Dr. Victor E. Lagarde III, Chief of the Environmental Systems Division (ESD), and Mr. Harold W. West, Chief of the Environmental Analysis Group (EAG), and under the direct supervision of Mr. Bruce Sabol, WES project coordinator. Messrs. Sabol and Tommy Berry prepared this report.

Commander and Director of WES during preparation of this report was COL Larry B. Fulton, EN. Technical Director was Dr. Robert W. Whalin.

This report should be cited as follows:

> Sabol, Bruce, and Berry, Tommy. 1991. Effects of Microtopographic Features on Tilt of the Wide Area Mine Ground Platform. Miscellaneous Paper EL-91-16. Vicksburg, MS: US Army Engineer Waterways Experiment Station.

Conversion Factors, Non-SI to SI Units of Measurement

Non-SI units of measurement used in this report can be converted to SI units as follows:

Multiply	By	To Obtain
degrees (angle)	0.01745329	radians
feet	0.3048	meters
inches	0.0254	meters
pounds (mass)	0.4536	kilograms
square inches	6.4516	square centimeters

1 Introduction

Several critical functions of candidate Wide Area Mine (WAM) systems are affected by the off-vertical angle of the ground platform (tilt) erected on the terrain surface. Extensive topographic slope information is available for anticipated theaters of operation; however, these data are based on small-scale maps and digital elevation data with a coarse grid spacing (100+ ft).[1] A very limited amount of digital terrain data is available with a high resolution grid spacing (8 ft). The actual tilt of the WAM ground platform is determined by the terrain surface topography directly under the platform's base and extended legs—an area about 2 ft in diameter. High resolution data are not presently available to estimate the distribution of tilt angles for a WAM ground platform.

To fill this gap, a short-term study was performed to determine the tilt-angle distribution of WAM surrogates on various terrain surface types. A pre-erected (legs locked in open position) WAM surrogate was provided to the US Army Engineer Waterways Experiment Station (WES) by each contractor (Honeywell Inc. [HI], and Textron Defense Systems [TDS]). Measurements of tilt angle were made for each model for replicate random placements on four separate terrain surfaces. Procedures and results of this study are described in the following paragraphs. It should be noted that this study did not consider the erection process; therefore, these data should not be interpreted as tilt angles resulting from realistic deployment of WAMs.

[1] A table of factors for converting non-SI units of measurement to SI (metric) units is presented on page vii.

2 Procedures

Mass Models

Surrogates of the Honeywell and the Textron WAM ground platforms were provided to WES in early June 1989. Both came with erecting legs already deployed (locked in place for TDS surrogate). The configurations of these surrogates are consistent with the Proof-of-Principle (POP) WAM design except that the HI surrogate was 35 lb as opposed to the 60-lb WAM used in the POP erection demonstration. Physical measurements of each are contained in Table 1. Photographs of each are contained in Figure 1. The HI surrogate was furnished with information (Appendix A), contrasting it with the POP and full-scale engineering development (FSED) designs of the platform.

Site Descriptions

Three nominally flat sites were selected in the vicinity of Vicksburg, MS. These include a fallow field, a meadow, and an active field. The active field site was freshly plowed and used for one set of tilt measurements (referred to as newly plowed field site). It was subsequently replowed and rowed and used for a second set of tilt measurements (referred to as plowed and rowed field site). Photographs of each site are shown in Figures 2 through 5. All sites had an average slope of less than 1 percent (1 ft vertical to 100 ft horizontal). The site's microtopographic roughness was determined by surveying the elevation of at least 30 points (to the nearest 0.04 in.) in a localized area (20-ft-diam circle) with each point approximately 1.5 ft from its nearest neighbor. The root mean squares (RMS) of these elevations were computed for each site and expressed in inches. Soil bearing strength was estimated by taking six 0.2-sq-in. cone penetrometer measurements at each site. Site descriptions are summarized in Table 2.

Tilt Measurements

At each site, the surrogates were repeatedly placed at randomly selected locations. A random sampling procedure (without replacement) called for the tester to walk along a selected path and drop the surrogate (from a height of about 1 ft) at random times while looking away from the drop point (to avoid subjective placement). Figure 6 offers photographs illustrating this procedure. At the plowed and rowed field site, the tester selected paths perpendicular to the rows. Tilt of the surrogate was manually measured to the nearest 0.5 deg using a Mayes inclinometer.

Sample size used at each site was based on the desire to have an average of five replicates for each 1-deg tilt angle bin. The sample size was five times the second largest tilt angle measured (of either surrogate) or in no case less than 50 samples or more than 100 samples.

Resulting tilt angle measurements are graphically depicted in Figure 7, cumulative tabulation is shown in Table 3, and a statistical summary is contained in Table 4.

3 Results and Discussion

The four sites selected represent a range of conditions for managed and agricultural lands, and are probably good analogs for similar land use practices in Europe. The only land type obviously missing from this group is actively cultivated land with crops such as corn, wheat, barley, or sugar beets. The meadow site, however, may provide a close analog because of its dense grass vegetation.

The tilt angles appear to be normally distributed at each site for each surrogate (Figure 7). The mean tilt of each generally increased with surface roughness. The plowed field site was the exception to this, exhibiting a relatively high mean tilt and a relatively low RMS roughness. This site differed from the others in that it had a higher spatial frequency for roughness; several local maxima and minima could occur over a distance of 2 ft.

At all sites the Textron surrogate had a higher mean tilt angle and greater variation in tilt angle than the Honeywell surrogate. A Kolmogorov-Smirnov two-sample test was performed on data at each site to determine whether the apparent difference was statistically significant ($p \leq 0.05$). Only at the plowed field site was the difference significant.

Table 1
Physical Measurements, WAM Mass Models

Characteristic	Honeywell	Textron
Weight, lb	34.5	35.8
Height, in.	14.5	14.0
Diameter of body, in.	7.2	8.0
Number of legs	19	8
Width of individual leg, in.	1.0	2.8
Base diameter with legs extended, in	21.5	23.6

Table 2
Summary of Site Characteristics

Descriptors	Site: Fallow Field	Meadow	Plowed Field	Plowed and Rowed Field
Location	Vicksburg Airport	Vicksburg Cross Creek Farm	Vicksburg Cross Creek Farm	Vicksburg Cross Creek Farm
Date sampled	7 July 89	19 July 89	21 July 89	9 Aug 89
Surface description	Grass - old bean field soft saturated ground	Grass - meadow, firm ground	Broken, 5 passes by disk	Rowed - 30 in. apart 4-8 in. high
Soil description	Clayey silt (ML)	Clayey silt (ML)	Clay (CL)	Clay (CL)
Surface roughness, in. RMS	1.04	0.72	0.76	1.84
Mean Cone Index by Depth				+
Depth, in.	**Index**			
0	20	140	40	40
1	50	260	70	230
2	60	340	180	350
3	100	400	290	370
4	140	440	370	450
5	160	490	390	470
6	160	490	370	587
9	170	490	240	520+
12	200	450	260	590+
15	140	430+	430+	470+
18	160	410+	620+	430+

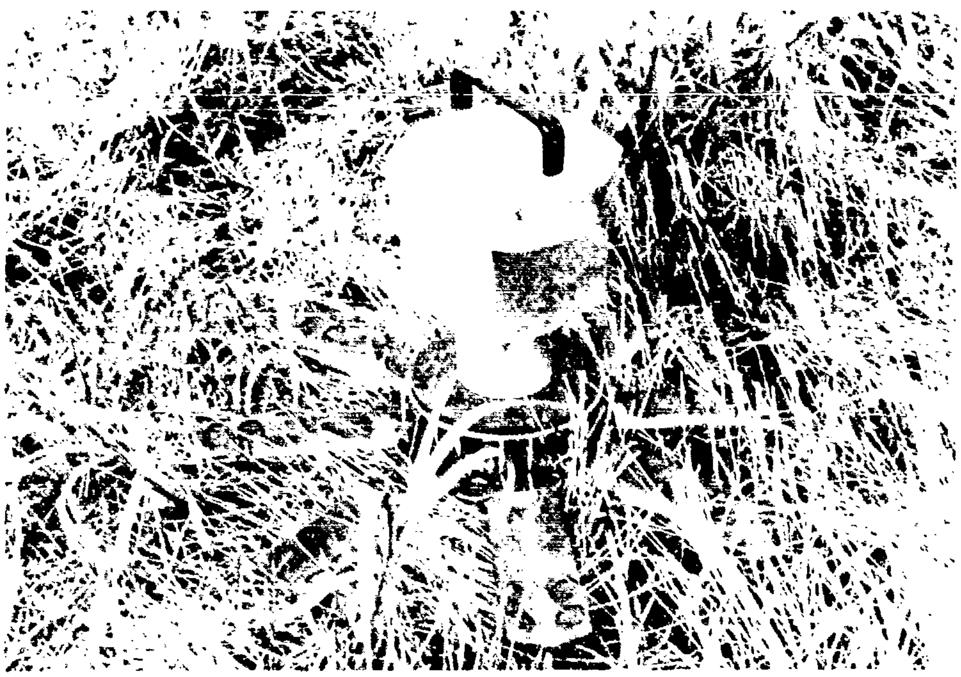
Table 3
Cumulative Distribution of Tilt Angle Measurements

Angle deg	Fallow Field (n = 57)		Meadow (n = 50)		Plowed (n = 90)		Plowed and Rowed (n = 100)	
	HI	TDS	HI	TDS	HI	TDS	HI	TDS
0	1.8	3.5	4.0	4.0	1.1	0.0	0.0	0.0
1	8.8	10.5	30.0	20.0	4.4	4.4	2.0	0.0
2	28.1	21.1	66.0	52.0	17.8	13.3	4.0	2.0
3	50.9	38.6	86.0	72.0	32.2	22.2	7.0	7.0
4	68.4	54.4	92.0	84.0	47.8	38.9	10.0	12.0
5	84.2	70.2	98.0	88.0	65.6	52.2	17.0	18.0
6	93.0	82.5	98.0	96.0	83.3	62.2	26.0	22.0
7	98.2	91.2	98.2	98.0	86.7	72.2	32.0	34.0
8	100.0	93.0	100.0	98.0	91.1	78.9	38.0	38.0
9		93.0		100.0	91.1	82.2	42.0	41.0
10		96.5			96.7	90.0	50.0	50.0
11		98.2			96.7	92.2	58.0	57.0
12		98.2			98.9	94.4	65.0	61.0
13		98.2			98.9	96.7	75.0	65.0
14		98.2			100.0	97.8	80.0	73.0
15		98.2				97.8	83.0	76.0
16		98.2				97.8	88.0	79.0
17		100.0				97.8	94.0	85.0
18						98.9	96.0	90.0
19						98.9	98.0	93.0
20						98.9	98.0	95.0
21						98.9	99.0	98.0
22						98.9	99.0	99.0
23						100.0	100.0	99.0
24								100.0
25								

Table 4
Statistical Summary of Tilt Measurements, deg

Statistics	Site							
	Fallow Field		Meadow		Plowed Field		Plowed and Rowed Field	
	HI	TDS	HI	TDS	HI	TDS	HI	TDS
Sample size	57.0	57.0	50.0	50.0	90.0	90.0	100.0	100.0
Mean tilt deg	3.5	4.5	2.1	2.8	4.7	6.0	10.2	10.9
Standard deviation	1.8	2.9	1.4	1.8	2.7	3.8	4.8	5.4
Minimum	0.0	0.0	0.0	0.0	0.0	0.5	1.0	1.5
Maximum	7.5	17.0	7.5	8.5	13.5	23.0	23.0	23.5

a. Honeywell



b. Textron

Figure 1. Photographs of WAM mass models

Figure 2. Fallow field site

Figure 3. Meadow site

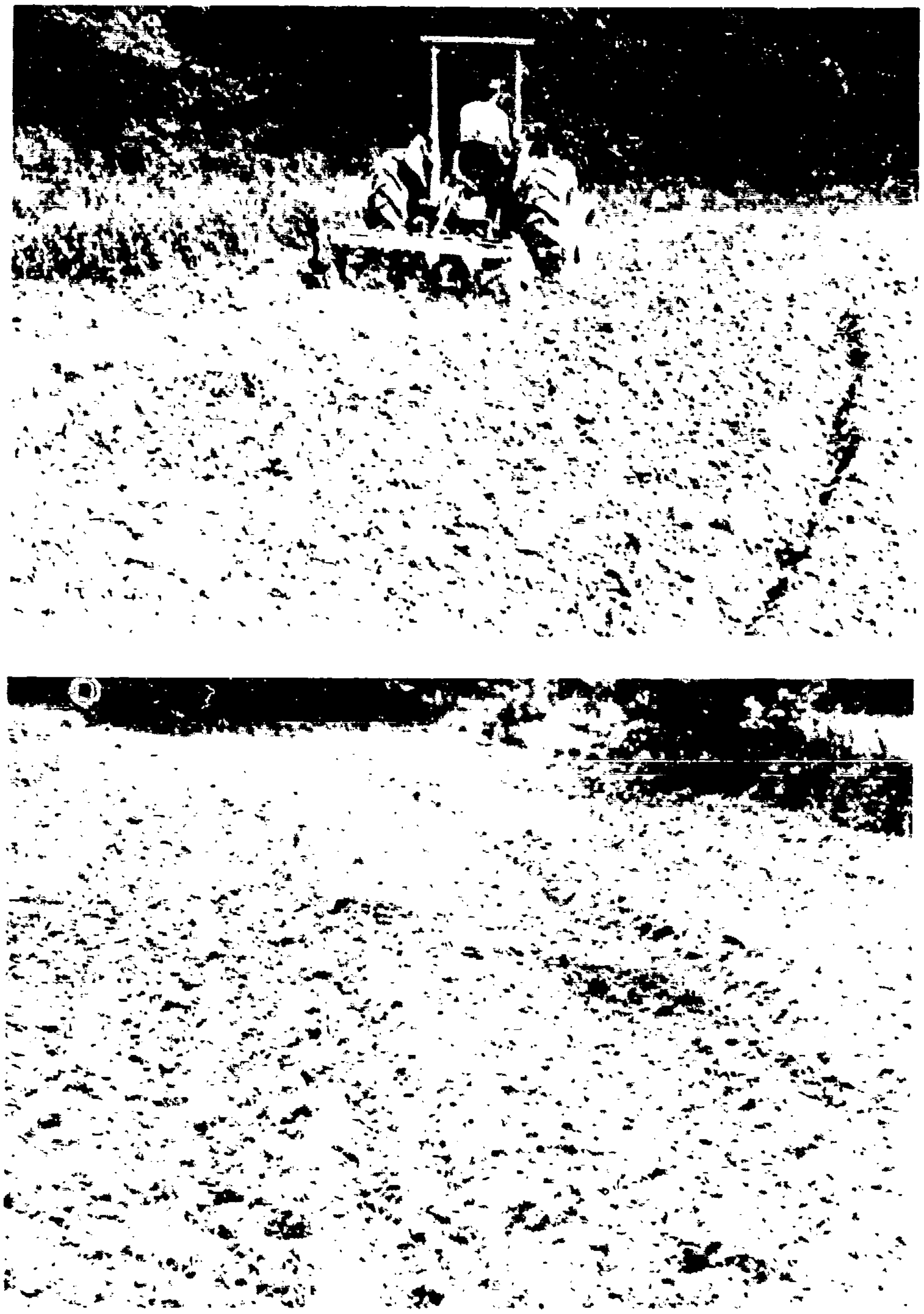


Figure 4. Plowed field site

Figure 5. Plowed and rowed field site

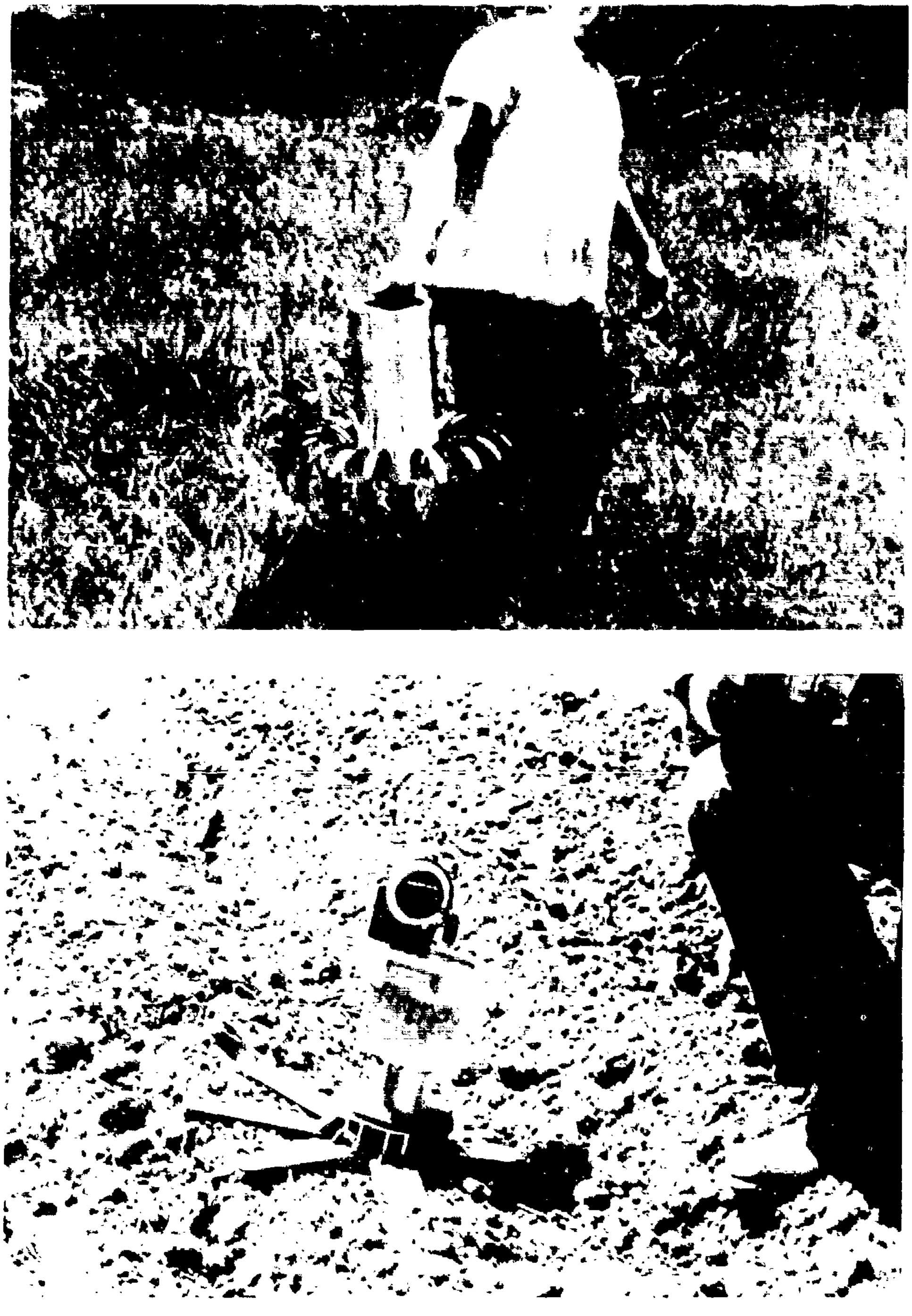


Figure 6. Tilt angle measurement

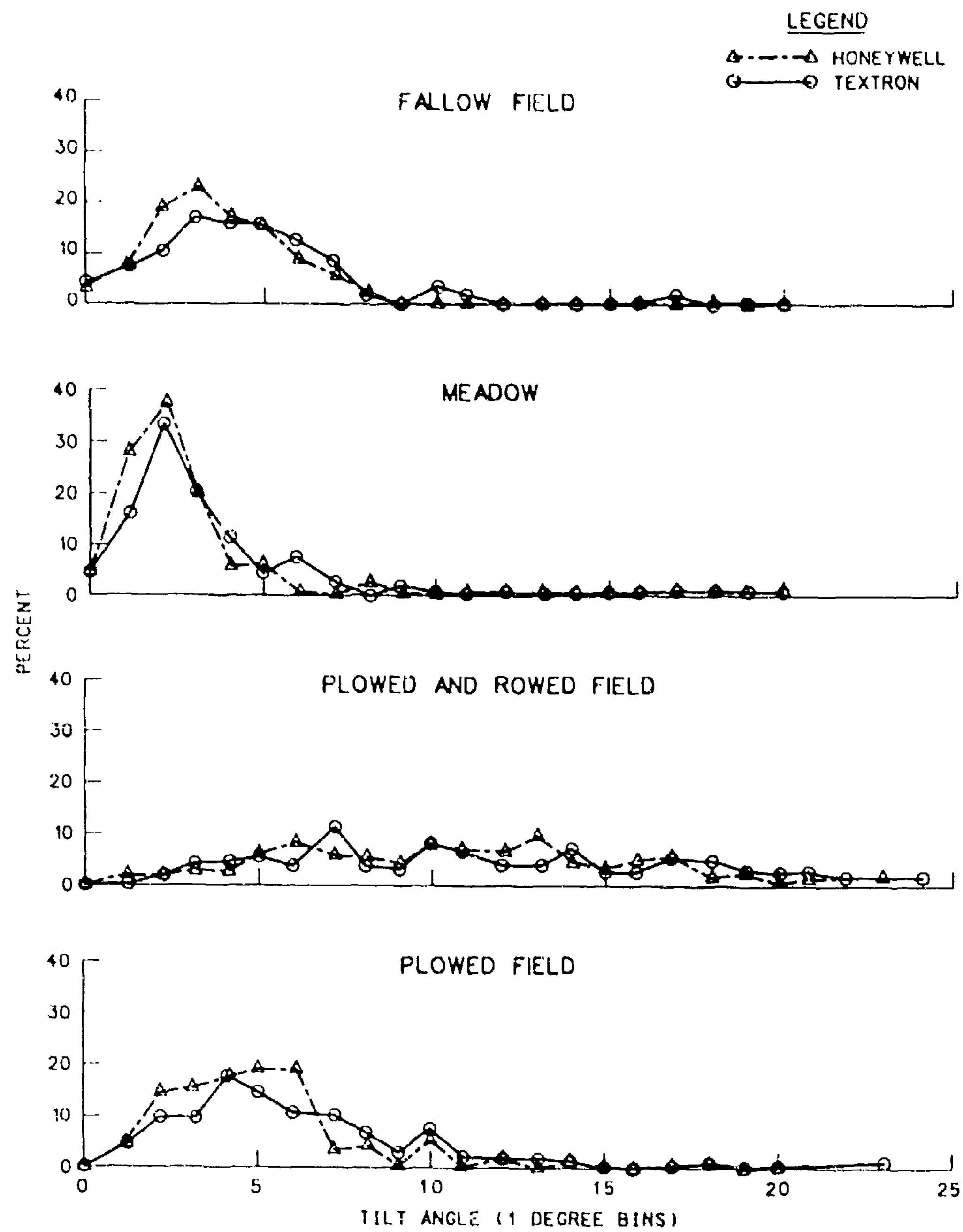


Figure 7. Frequency polygon of WAM tilt angles at four sites

Appendix A
Configuration of Honeywell Surrogate

Honeywell

June 5, 1989

Mr. Bruce Sabol (EN-A)
Waterways Experiment Station
3909 Halls Ferry Road
Vicksburg, Mississippi 39180

Subject: WAM Erecting Mass Model

Dear Bruce:

Per our conversation on 31 May, I am providing the configuration of the mass model sent to you. I have also detailed the differences between this model, the PoP hardware tested in the erecting demo, and our current FSED baseline. This information is summarized below.

Physical Parameters:

	Mass Model	PoP Erecting Demo	FSED Baseline
Weight	35 lbs	60 lbs	35 lbs
Length	14.25 in	14.25 in	16 in
Center of Gravity	7.1	6.8 in	8.0
Spring Material	Stainless Steel	Stainless Steel	Composite

Similarities and Differences Between Mass Model, PoP, and FSED

Number of Springs:

The FSED baseline is a single layer of 18 composite springs. The force required to straighten one of these springs is approximately 45 lbs. The mass model sent to you has a double layer of stainless steel springs. The force required to straighten a set of these springs is also 45 lbs, simulating the FSED baseline. The PoP Demo hardware had alternating double and single layers of stainless steel springs.

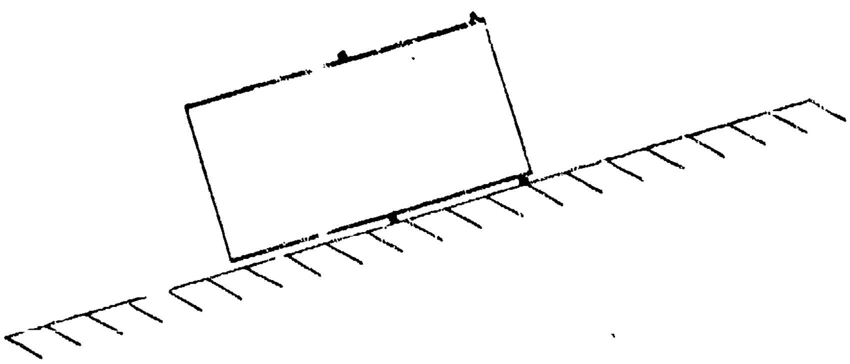
DEFENSE SYSTEMS GROUP
HONEYWELL INC., 5901 SOUTH COUNTY ROAD 18, EDINA, MINNESOTA 55436, TELEPHONE 612/939-2000

Page Two
Mr. Bruce Sabol

Release Method:

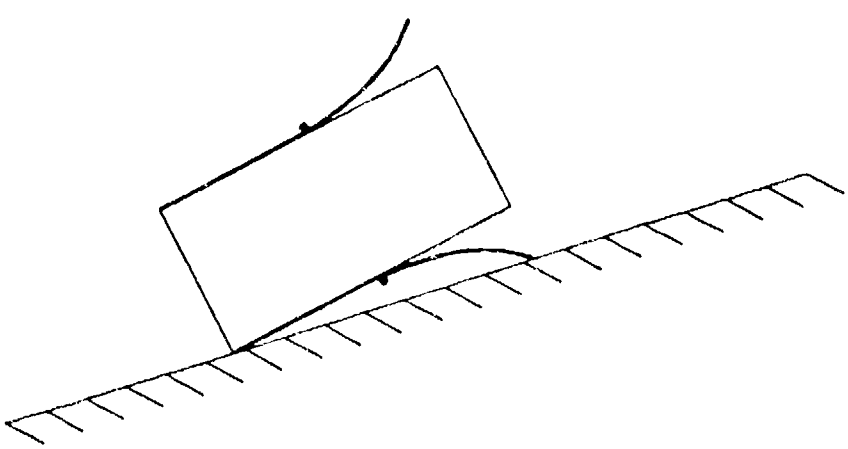
The PoP erecting springs were restrained with a single cable at the top of the unit. The FSED baseline is to use a 2-stage release of the erecting springs. This method of release allows the spring energy to be delivered in a controlled manner which provides sufficient force in uphill conditions while not overpowering the unit in downhill conditions. This concept is shown below:

- prior to deployment



The erecting springs are restrained by two cables, one at the top of the unit and one at the mid-point of the mine.

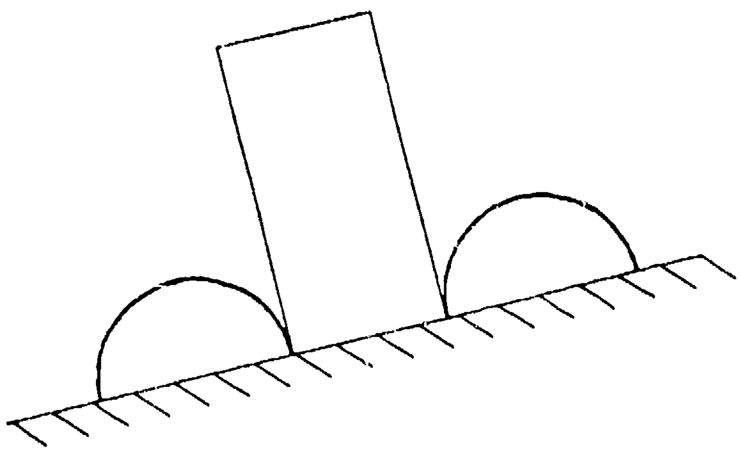
- 1st stage release



The top cable is cut allowing the unit to partially erect.

Page Three
Mr. Bruce Sabol

- 2nd stage release



The second cable is cut which releases the remaining energy in the springs and completes the erection.

Testing completed to date showed good performance under all conditions. The problem of the mine flipping in the hard surface, downhill condition was eliminated. In addition, in the soft soil, uphill condition the mine was erected to a position much closer to normal to the local terrain than seen in the Erecting Demo. This is due to the controlled release of the spring energy reducing the disturbances to the soil.

Spring Curvature:

The mass model sent to you and the Erecting Demo hardware use the same erecting springs. In the FSED baseline the radius of curvature of the spring will be greater which will reduce the tendency of the spring to "tuck under". This should increase the overall stability of the mine.

Page Four
Mr. Bruce Sabol

This summarizes the physical configuration of the mass model sent to you, as well as detailing some of the similarities and differences between the PoP and FSED designs. If you have any questions or need more information feel free to call me at 612-939-2229.

Sincerely,

Timothy J. Kensok

Timothy J. Kensok
Honeywell, Inc.

TK jd
103TK